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ELECTRON DETECTORS FOR VACUUM PRESSURE RISE DIAGNOSTICS AT RHIC*

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Abstract

In the RHIC 2001 run, an unexpected vacuum pressure rise versus bunch increasing currents was observed in both gold and proton operations. This pressure increase due to molecular desorption is suspected to be induced mainly by electron multipacting, but other causes may coexist, such as ion desorption due to halo scraping. In order to get a reliable diagnostic of the phenomenon electron detectors have been installed along the RHIC ring. In this report we describe results measured by the electron detectors with energy filters during the RHIC 2002/2003 run.

1. INTRODUCTION

A pressure increase was observed during Au-Au FY2001 run at the Relativistic Heavy Ion Collider (RHIC) for high intensity beams. It is suspected to be due to molecular desorption, mainly substained by electron multipacting, but other causes may coexist, such as ion desorption or beam losses as seen in Ref. [1]. In order to have a reliable diagnostic for the phenomen, up to 16 electron detectors (ED) have been installed in the RHIC ring. Since the presence of ions is not rejected [1], ion collection will be possible through these detectors. A general description of the ED installed at RHIC follows:

- 4 Spallation Neutron Source (SNS) ED, and 1 Argonne National Laboratory (ANL) ED. Both of these ED are RF shielded very effectively and in a similar manner. No amplifiers were connected to them, and they all could be used to measure an electron energy (E_e) spectrum.
- 1 MicroChannel Plate (MCP) ED. Its low frequency cut off (f_{low}) is set to 0.3MHz, and it has a nominal gain (G) of 58dB. No E_e spectrum is available through this detector.
- 11 RHIC ED. Their design is based on the PSR model [2], and a general layout can be seen in Fig. 1. Most of these ED's are connected to the AC coupling amplifier *Sonoma* 310 (G=32 dB, bandwidth (BW) [10kHz-1GHz]). The final f_{low} ranges from 10kHz to 1MHz since it is a function of the Capacitor (C) used to protect the amplifier. An E_e spectrum is also possible through these detectors.

As a first measure to reduce the pressure (P) rises detected during RHIC 2001 run, most of the warm parts of the ring were baked out before the FY2003 run. Despite the fact that the ring was filled several times with the same fill patterns as in 2001: 55 and 110 bunches, 216ns and 106ns bunch spacing, respectively. See Ref. [1] and [3] for more information. P rises were not as strong and generally reproduced around the entire ring, but only in certain locations. The bake out, together with the lower beam intensities achieved during this run, produced very low electron currents to the beam pipe wall. Therefore, only the EDs placed at very weak parts (in terms of vacuum stability) and with a high G were able to detect currents above the noise level. For technical reasons the MCP (58dB) was not fully utilized. Therefore, the RHIC ED has been the main ED providing electron cloud EC signals, and this note will report about the description of this detector.

2. THE RHIC DETECTOR LAYOUT

The general layout of the RHIC ED can be seen in Fig. 1. The top grid ('Grid 0' in Fig. 1) acts as an RF shield, and its transparency (T_0) is fixed to 23% in order to decrease the effect of the image currents without interfering the multipacting process. The middle grid (stated in Fig. 1 as 'Grid 1', with $T_1 = 80\%$) can be biased to different voltages through the remote controlled High Voltage supply (HV). It acts as an energy filter, allowing the E_e spectrum to be measured.

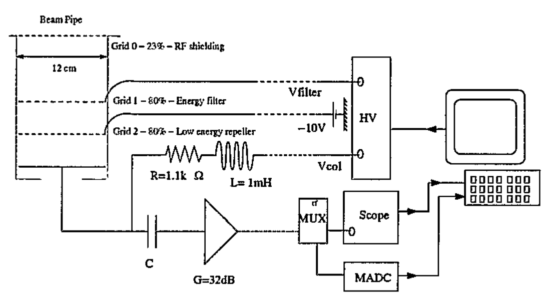

Figure 1: Layout of the RHIC ED. As stated in the text, C is not the same for all 11 detectors, but a typical value is 0.01 μF. The presence of C is needed to protect the amplifier.

The bottom grid (shown as 'Grid 2' in Fig. 1, with $T_2 = 80\%$) is held at -10V by a DC battery. It is used as a repel back the secondary electrons produced at the collector. The collector can be biased either positively or negatively through another output of the HV supply in order to check the presence of either electrons or ions, respectively

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[1]. In order to be able to keep the collector at different voltages and polarities without damaging the amplifier, an RLC circuit (Fig. 1) is used in a box placed as close as possible to the ED in the ring. The multiplexer (shown as 'MUX' in Fig. 1) allows for signal splitting and two data acquisition modes: 'fast' and 'slow'. The fast mode uses a scope to take a $20\mu s$ snapshot sampled at 1GHz which is done through the scope. This acquisition is triggered every AGS [1] cycle (approximately every 4s). The 'slow' mode uses a Multiplex Analog to Digital Converter (MADC) with a sampling rate of 720 Hz. This mode should be useful in linking the time evolution of P and I_{wall} for large time scales.

Signal differentiation

An AC coupled system differentiates the signals below the f_{low}, which is determined by C. The RHIC ED circuit has been evaluated using the commercial software $PSPICE$ [2], and its behavior has been tested for a given 'ideal' I_{wall}. This I_{wall} has been taken from one of the existing computer EC simulation codes, in this case, $CSEC$ [5]. Figure 2 shows the signal differentiation when the EC starts. Although we are referring to an electron current which should always be negative (green light points in Fig. 2), the signal that will be seen in the scope (black line) is both positive and negative in order to keep the integral over one period null, i.e. one RHIC beam revolution, $\tau_{rev} = 12.8\mu s$. We can see that as the EC takes place, both the maximum and minimum parts of the signal increase in magnitude due to the electronics design. Using the MADC, we log the maximum and minimum values of the 720 samples taken per second and we can follow the slow evolution of EC at 1Hz. This will become the most reliable tool in evaluating the EC signal at large time scales (minutes).

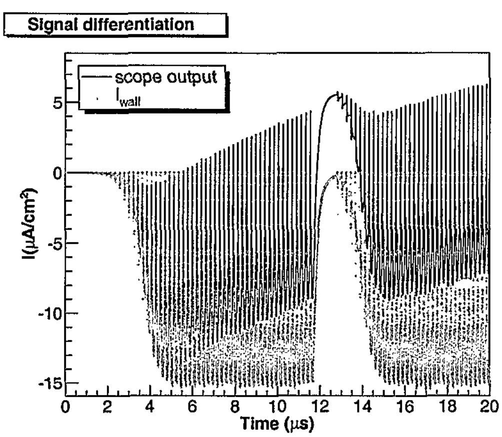

Figure 2: Theoretical I_{wall} calculated with $CSEC$ (green light dots). This signal is differentiated by the RHIC ED system, and has been evaluated with $PSPICE$ (black line).

[1]Alternating Gradient Source

[2]http://www.orcadpcb.com/pspice

Calibration

For a given scope voltage reading (V), we will be interested in the corresponding current into the wall (I_{wall}). Given the surface area of the detector, S_{ed}=78cm^2, and taking into account that the effective transparency (T_{eff}) of the ED is calibrated as a function of the E_e (see [4]), I_{wall} in terms of $\mu A/cm^2$ can be calculated as:

$$I_{wall} = \frac{V}{ZGS_{ed}T_{eff}}, \tag{1}$$

where $Z = 50\Omega$, and according to the specifications of the amplifier, G is significantly flat for the f we are interested in (80kHz to 20MHz). Therefore, the uncertainty in T_{eff} will be responsible for the error while computing the I_{wall} from the experimental data (V).

3. EXPERIMENTAL RESULTS

During this run, d circulated in the clockwise RHIC ring (blue ring), and the Au^{79+} ions ran in the counterclockwise RHIC ring (yellow ring). The typical intensities have been I_{pb}=6 10^{10} d per bunch (*dpb*) in the blue ring, whereas in the yellow ring I_{pb}=4 10^8 Au^{79+} ions per bunch *Aupb*. These numbers are below the EC threshold in both cases. Together with the bake out, these facts produced some less severe P increases (see [3] for more details), and the possibilities of detecting electrons were significantly reduced. On the other hand, during the polarized proton (*pp*) run starting in March 26th 2003, the beam intensities were readily attainable above the EC threshold, and an I_{pb}=10^{11} protons per bunch (*ppb*) was easily achieved. We analyze the data collected for both the dAu and pp run. Table 1 summarizes the experimental minimum beam parameters for which EC signals allow data collection using the ED.

Table 1: Experimental beam parameters producing EC signals at the RHIC ED. The beam bunch spacing is always 106ns, corresponding to the pattern for 110 bunches in the machine. Bunch length at injection is usually 15-20 ns, while when ramping it is about 10ns (head to tail). I_{wall} is estimated using T_{eff}=3.5% from [4].

	Au^{+79}	d	p
I_{pb}	8 10^8 $Aupb$	9 10^{10} dpb	8$10^{10}$ ppb
process	ramp	injection	injection
$I_{wall}(\mu A/cm^2)$	≈5	≈0.5	≈2
fill #	3107	3159	3460
P (torr)	5 10^{-6}	1 10^{-6}	4 10^{-6}

Fast mode observation

The Au case showed only one significat case of EC signal, and interested readers can see it in [3]. In the d case, no clear snapshots of data have been logged with ED. However, in several cases, by smoothing the data it is possible to distinguish the EC signal from the noise level and image currents. The most critical region in the blue ring turned out to be the straight section 'bo2'. The RHIC ED there has the same characteristics as seen in Fig. 1, except that it is equipped with 2 amplifiers in series. Therefore its total nominal $G = 64dB$. Fig. 3 reports the case of fill #3159, where I_{pb}=9 10^{10} dpb. When 59 bunches where injected in the machine, the raw data does not show any clear EC signal (light green dotted lines). Numerically smoothing the data with a 10 MHz filter (black line), we can clearly see how the EC rises for the last bunches and disappears at the same time as the bunch train.

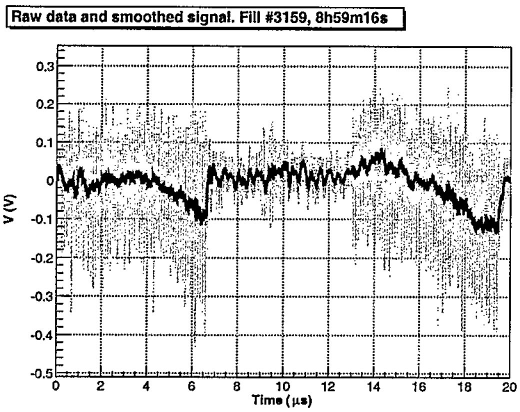

Figure 3: EC signal on the ED placed in the bo2 sector. The light dotted green line shows the raw data, whereas the black solid line shows the smoothed data using a numerical 10 MHz filter.

Slow mode observation

The ED placed in bo2 showed clear EC signals during the *pp* run using the 'smoothing' technique, and similar snapshots as in Fig. 3 are compared in [5]. Fill #3460 showed a general EC problem throughout RHIC. This clear case allowed us to carry out interesting studies using the 'slow' mode (MADC). Figure 4 shows the time evolution of P, and the V in the ED. The injection during this fill was temporally interrupted when 45 bunches were injected (t=250s, in Fig. 4). Injection resumed at t=320s and finished after 700 s. Correlation between the time evolution of P and V is visible, which shows that EC is the primary factor in the P rise. V is plotted in a linear scale, and it is worth mentioning that both magnitudes are ultimately a function of I_{beam}. Using Eq. 1, I_{wall} in this plot ranges from $0.2\mu A/cm^2$- $5\mu A/cm^2$.

4. CONCLUSIONS AND OUTLOOK

The EC could be observed with d, Au and p in the FY2003. P rises during the dAu run have in general been lower than expected due to the bake out performed during

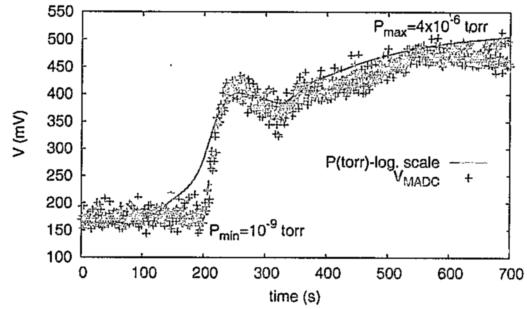

Figure 4: EC signal using MADC in bo2 sector while filling RHIC with 110 bunches. Injection was temporally interrupted after 45 bunches (t=200s) and resumed at t=320s. Note that P is plotted in logarithmic scale.

the 2002 shutdown and the technical difficulties in acieving high I_{pb}. However, under certain beam conditions, a substantial P rises were observed and several EC signals have been detected using the RHIC ED in the fast mode for both d and Au. The weak EC signal and the absence of an amplifier for the SNS and ANL ED did not allow the EC to be seen using these. In general, I_{wall} ranges [0.5-10] $\frac{\mu A}{cm^2}$. The RHIC ED has been very sensitive to of image currents, and signals below $\approx$0.5 $\frac{\mu A}{cm^2}$, corresponding generally to $P < 10^{-7}$ Torr were indistinguishable from the noise level. Only cases reported during the *pp* run allowed us to use the slow mode detection. The signal differentiation in the RHIC ED has been evaluated, and an estimation of the evolution of EC for large time scales (minutes) is possible. This fact allowed us to investigate the direct influence of I_{wall} on the P rise. A measure of the E_e spectrum, and a better estimation of the slow evolution of I_{wall} are in progress. A new DC amplifier is currently being designed and expected to be ready for use during the next run.

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REFERENCES

[1] W. Fischer et al. Vacuum pressure rise with intense ion beams in RHIC. Proceedings of EPAC'02, Paris, 2002.

[2] R. Macek et al. Recent experimental studies of the Electron Cloud at the Los Alamos PSR. KEK Workshop, Sept. 2001.

[3] S.Y. Zhang et al. RHIC pressure rise and electron cloud. In this proceedings.

[4] P. He et al. Calibration of RHIC Electron Detector. In these proceedings.

[5] U. Iriso-Ariz et al. Electron cloud and pressure rise simulations for RHIC. In these proceedings.